

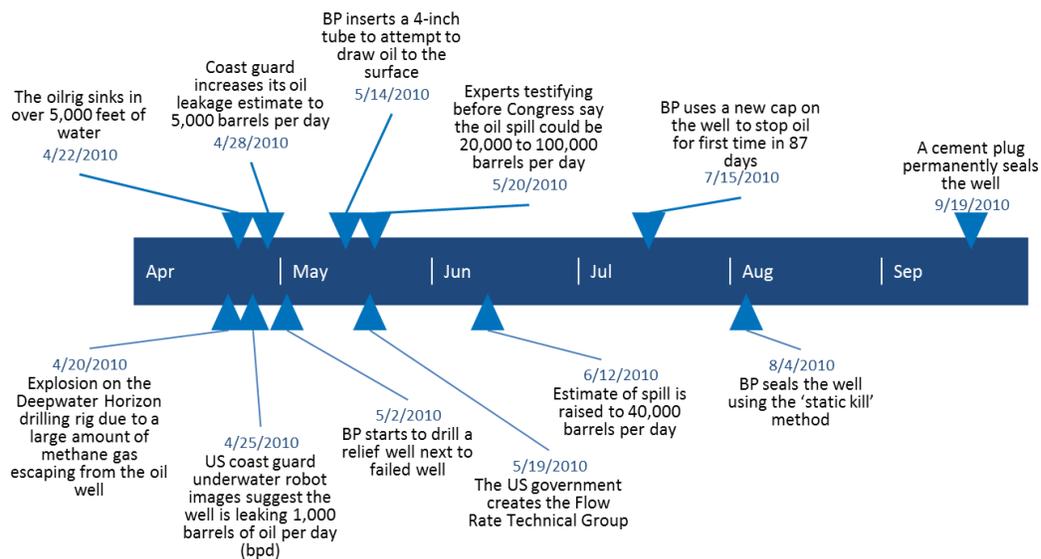
Policy Brief: Deepwater Horizon Oil Spill

Chidube Ezeozue, Stephen Maouyo, Julia Moline, Ralph Turlington, and Ekene Umeike

Background

On April 20th, 2010 the Deepwater Horizon drilling rig, a rig owned by BP, exploded in the Gulf of Mexico approximately 50 miles south of the Mississippi delta. The explosion and fire killed 11 workers and injured 17 others. The spill from the damaged Macondo oil well also created the second largest oil spill in history (1). At the time of the explosion, BP had licensed the rig from Transocean limited (2).

Figure 1: Timeline of Major Events (2)



Stakeholders

All response decisions during the Deepwater Horizon (DWH) spill were made within the National Incident Command Structure (ICS), under the direction of US Coast Guard (USCG) Admiral Thad Allen, who was appointed National Incident Commander (NIC). Admiral Allen reported directly to Department of Homeland Security (DHS) Secretary Janet Napolitano and oversaw the Federal Unified Command, which in turn coordinated several Unified Command offices in the various affected states. National and Regional Response Teams also contributed to response. This structure was in place to ensure that all involved agencies at the federal, state, and local levels could coordinate and effectively manage the incident. Key categories of stakeholders are discussed in detail in Table 1 (4)(10).

All stakeholders relied directly or indirectly on flow rate calculations to inform response strategies, analyses, and other decisions. Although there were many flow rate estimates in the weeks after the explosion, the sheer range of estimates and the uncertainty surrounding them, combined with the desire to appear in control of the situation and consistent in response, meant that Unified Command largely dismissed other estimates, even after it became clear that the official estimate was over an order of magnitude too low.

Table 1: Key Stakeholders in Deepwater Horizon

Stakeholder	Role	Interests	Stake in Flow Rate Calculations
Incident Command	<ul style="list-style-type: none"> Oversee response 	<ul style="list-style-type: none"> Rapid and efficient deployment 	<ul style="list-style-type: none"> Guide response efforts

Stakeholder	Role	Interests	Stake in Flow Rate Calculations
(US Coast Guard, US Navy)	<ul style="list-style-type: none"> Coordinate all entities, including information flows Answer to White House 	<ul style="list-style-type: none"> of resources Information sharing Retain official Incident Command Structure 	<ul style="list-style-type: none"> and resource deployment
Regulatory Agencies (EPA, NOAA, DOI/MMS, DOE, DHS)	<ul style="list-style-type: none"> Provide expertise on what was happening and why Develop strategies to contain flow Provide expertise on impacts of own and others' proposed strategies Liaise with academia, other analysis groups 	<ul style="list-style-type: none"> Ensure goals of agency are met (e.g. environmental protection) Ensure regulations are enforced Protect own reputation/position of authority 	<ul style="list-style-type: none"> Inform other calculations, e.g. oil budget Inform estimates/models for long-term and ongoing impacts
White House	<ul style="list-style-type: none"> Pressure Incident Command for rapid action Pull in key stakeholders needed in analysis 	<ul style="list-style-type: none"> Rapid resolution Appear "on top of" the situation for the general public 	<ul style="list-style-type: none"> No specific stake
State Governments (LA, AL, MS, TX)	<ul style="list-style-type: none"> Manage/deploy own resources Liaise with affected local jurisdictions 	<ul style="list-style-type: none"> Limit damage to own turf Stop decisions that would unfairly impact own states 	<ul style="list-style-type: none"> Understand impacts to states, to localities Limit adherence to federal command
Local Governments	<ul style="list-style-type: none"> Provide resources and personnel for response Manage locality-specific issues 	<ul style="list-style-type: none"> Limit damage to own turf Provide support to state and federal operations 	<ul style="list-style-type: none"> Understand local impacts Fill perceived gaps in assistance to constituents
BP	<ul style="list-style-type: none"> Provide data for review and analysis Conduct analyses and present to decision makers Participate in efforts to stanch flow 	<ul style="list-style-type: none"> Salvage reputation Minimize losses (oil, equipment) 	<ul style="list-style-type: none"> Influence response strategy

Other stakeholders not directly involved in decision making included local business owners (fishers and farmers) whose livelihoods were at stake because of the spill, international governments (Mexico and Cuba) whose waters were impacted by the spill, and environmental advocacy groups. In addition, the Deepwater Horizon Spill carried with it intense and sustained public scrutiny, including live-streamed underwater footage of the spill. As a result, the media, and by extension the general public, essentially became stakeholders in decision-making. This scrutiny added to the pressure of the situation and increased decision makers' desire to appear in control.

Flow Rate

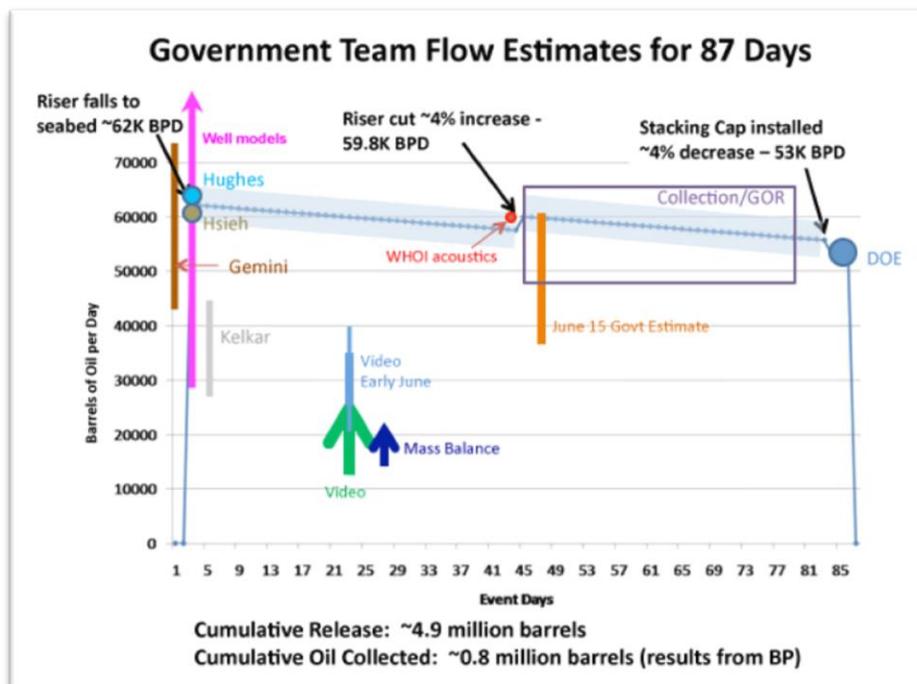
The Macondo well flow rate was difficult to estimate, but was critical to a number of decisions. First, the flow rate helped the government assess the required level of response and was used as justification to trigger National Incident Command protocols. Second, the deployment of resources on the Macondo blowout site was determined based on the perceived amount of oil spilling into the Gulf. Third, the amount of oil released was needed to determine the threats posed to the surrounding ecosystems. Finally and importantly, the amounts being released were needed to determine the efficacy of the well kill systems (Appendix A).

On April 24th, Unified Command announced that the oil was leaking from the riser at a rate of 1,000 barrels per day; this number likely came from BP, although the methodology by which it was calculated remains

unclear. By April 26th, the official government estimate rose to 5,000 bpd based on estimates from BP and the National Oceanic and Atmospheric Administration (NOAA) estimates. This remained the government’s official estimate through the end of May and was used to determine the USCG’s dispersant strategy. However, as BP revised its estimates upward, BP began to make containment decisions based on flow rates of as much as 14,000 bpd. As independent scientists and, later, the Flow Rate Technical Group (FRTG) began to release estimates ranging from 20,000 to 100,000 bpd, and as BP’s containment efforts (including the failed *Top Kill*) were overwhelmed, Unified Command began reconsidering its own strategies. In fact, Admiral Allen noted that the FRTG’s higher estimates spurred the USCG to consider other strategies in addition to the original dispersant strategy.

By mid-July, estimates had converged to 50,000-60,000 bpd. These estimates fed into the calculation of the oil budget, which was developed to account for all spilled oil. The oil budget was used to help model environmental impacts as well as to determine financial liabilities, losses, and aid. **Error! Reference source not found.** illustrates the range of estimates made over the course of the 87 day response (10).

Figure 2: Overview of flow rate estimates over time (9)



Modelers

For the reasons discussed above, estimation of the flow rate was critical to the mitigation of the DWH oil spill and several groups were consequently involved in the effort. One of the first groups commissioned by the NIC was the Government-Led Science Team (GLST) led by Dr. Steven Chu, Secretary of Energy, and Tom Hunter, then Director of Sandia National Labs. The GLST’s focus was not solely on the flow rate estimation; rather the “GLST was designed to bring unconventional thinking to bear on DWH problems” and its “members were chosen for their critical thinking skills, broad knowledge of relevant science and engineering, and willingness to be available” (7). Members included scientists from various Department of Energy (DOE) national laboratories, the U.S. Geological Survey (USGS), NOAA, academics, among others. Throughout the oil spill response, the GLST monitored, contributed to, and suggested further developments in the estimation of flow rate. The fact that the GLST was mainly composed of government scientists and academics lends to the

legitimacy of their estimations of flow rate to the NIC, who was responsible for decision making on behalf of the U.S. government and citizens; interestingly, the GLST sometimes brought in “experts from other major oil companies” which resulted in “substantial, comprehensive, and independent advice to the President and the NIC (7),” a fact that suggests a moderation of any possible bias.

The group most involved in flow rate estimation was the Flow Rate Technical Group (FRTG), established by the NIC’s Interagency Solution Group. It “included individuals from academia, government, and industry” (7), suggesting that the interests of all stakeholders, albeit not in equal parts, were taken into account. The FRTG was charged with two missions: 1. to “quickly generate a preliminary estimate of the flow rate from the Macondo well”; and 2. to “use multiple, peer-reviewed methodologies to generate a final estimate of flow rate and volume of oil released (6).” It is in the latter mission that the importance of the credibility of the assessments, not only the legitimacy attested to by the makeup of the assessment teams, appears imperative. The FRTG was headed by USGS Director Marcia McNutt and operated under the notion that “the best way to deal with the research nature of the problem was to have multiple independent teams use different methods” (6).” This suggests that the FRTG, in process and review, took a balanced approach to flow rate estimation.

Partly due to the direction taken by the FRTG and partly due to the magnitude of the disaster, there was no shortage of groups officially or unofficially developing flow rate estimations with an equal number of methods to back them up. The FRTG, the Woods Hole Oceanographic Institute, five DOE national laboratories, the USGS, the Bureau of Ocean Energy Management, researchers from Louisiana State University and University of Tulsa, the Gemini Solutions Group (an industry group), and NASA were all involved in flow rate estimation. The scientific credibility of selected assessments will be discussed below. The preponderance of academic and government institutions suggests that it was believed that the interests of the public and the government would be best served by academics and government scientists; the minority presence of the private sector indicates that a variety of opinions and interests were, nevertheless, taken into account.

Flow Rate Models

Although a number of models were used in estimating the flow rate, the unique nature of this spill (in magnitude and water depth) meant that no models had been tested on this specific type of problem previously. The most similar situation occurred during the Ixtoc I Mexican well blowout of 1979 and was in much shallower water - 160 feet versus 5000 feet (6). As a result, models that had been used for other purposes had to be modified and applied to the problem, and a wide range of values were suggested.

Accuracy, which was nearly impossible to obtain in the initial days of the spill, was nevertheless critical given the proposed uses of the flow rate estimates. More details for better model estimation became available as time went on, among them a) an opportunistic shut down in oil collection that allowed scientists to look for changes in the oil plumes in the video feed and b) pressure gauges installed on a containment cap that allowed scientists to get pressure readings at the wellhead. There was therefore a trade-off in the models between accuracy (which increased with increasing knowledge of model parameters) and timeliness. This tradeoff is explored in two specific models below.

John Amos (Skywatch.org) Visible Sheen Model

One of the earliest estimates for the flow rate was developed by John Amos of skywatch.org (9). It derived from satellite images of the oil spill taken about seven days after the incident. This simple model utilized the observable area of the spill and some estimate for the thickness of the observations to generate the volume of oil that had been spilled. Dividing this value by the number of days the spill had occurred for (at the time, seven) provided a rough estimate of the flow rate (11). Images of the oil slick were obtained from the NASA satellite Terra (12). A lower limit on the oil volume was obtained as 5,000 bpd using the minimum visible thickness of the oil sheen (1 micron). An upper limit of 20,000 bpd was then calculated using a claim from a BP official that the sheen was as thick as 100 microns in up to 3 percent of the oil sheen (11).

Even though this method provided estimates significantly higher than USCG's 5,000 bpd, it underestimated the flow rate because it did not account for the areas of the slick that were too thin to be visible. It also did not account for oil which had evaporated, burned with the rig, been collected or dispersed by response crews or was still below the surface. Another major flaw in this method is that it relied on the BP official's estimate of the sheen thickness, a number that was not supported by any obvious evidence. This method was, however, a precursor of the mass-balance method (6) later employed by the FRTG, which estimated the thickness of the sheen from its visible characteristics. In retrospect, while this simple calculation by John Amos underestimated the generally accepted flow rate (8) by over 60 percent, it was done by an independent scientist using all the data publicly available at the time and was useful in highlighting the egregiousness of the official government estimates at the time and pushed the government to step up flow rate calculation efforts eventually leading up the establishment of the FRTG.

USGS Reservoir Model (12)

At the other end of the accuracy-timeliness spectrum, one of the most definitive estimates of the flow rate was obtained in August 2010 by a building a model of the reservoir, accounting for flow through the well and estimating the flow at the wellhead using standard fluid mechanics principles. This USGS-developed method had the following input variables: original oil in place, determined by modeling the reservoir as a long, narrow channel with a rectangular cross-section and incorporating the porosity; formation volume factor, which determines how the volume of oil changes between the pressurized conditions in the reservoir and surface conditions, effective formation compressibility; oil viscosity, compressibility and density; and water saturation and compressibility. Other parameters include the coordinates of the Macondo well relative to the reservoir, permeability and coefficient of pressure loss in the well. The underlined parameters could not be measured and had to be estimated using "history matching", in which a parameter search is done until measured pressures match estimated pressures. MODFLOW (5), a USGS model used to simulate groundwater in aquifers was used to simulate oil flow through the reservoir and thus obtain the reservoir pressure at the well face. PEST (3) was used for parameter estimation. Both tools have been cited several hundred times in the literature indicating a wide level of acceptance and use.

This model determined an initial oil flow rate of 63,600 barrels per day (bpd) and a final rate (just before shut in) of 52,600 bpd as well as a total of 4.92 million barrels of oil discharged. The uncertainty of all estimated values was ± 10 percent. The sensitivity of the estimates to the input variables was also determined by varying the input variables by up to ± 25 percent and performing the simulations again. Some of the assumptions used in the creation of the model included that the flow of oil was under single-phase (all liquid) and isothermal conditions; reservoir properties (permeability, porosity and compressibility) were the same throughout the reservoir and permeability and viscosity were independent of pressure.

Despite the accuracy and authority of this model's output, its usefulness in the shut-in efforts was limited by its late development and reliance on the pressure measured at shut in. It was also not useful for determining containment capacity for similar reasons. It may have informed some part of the decision about the static kill method used to provide a final solution to the disaster especially by throwing light on why BP's initial Top Kill method failed. Arguably, however, this model was most useful for serving as an input to the oil budget calculations and models. The official releases of oil budget were based on the total amount of oil spilled as simulated by this model. Another major contribution of this model is the scientific advancement of being able to simulate worst-case discharge from other deep water drilling operations.

The credibility of the model may have been impacted somewhat by its reliance on BP data and the general public's perception of BP as dishonest given their very low initial estimates of the flow rate and their general tendency to play down the severity of the incident. Additionally, since a lot of the BP data relied on is proprietary, a lot of the data that was used as input for the model were not made publicly available for independent verification and validation.

Discussion Questions

1. Did the government make the right decision in allowing BP to run response operations? What were the benefits and drawbacks of doing so?
2. The FRTG and other parts of Unified Command turned to BP's competitors for flow rate estimates and suggestions. Did this make estimates more or less legitimate, and why?
3. Why would the government hold so steadfastly to a flow rate number that, after the fact, even they admitted seemed low? Were they justified in sticking with 5,000 bpd, or should they have changed their estimates--if so, which estimate should they have used, and what might the repercussions have been?

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Appendix A: Importance of the Flow Rate

Determining Intervention Success

In the aftermath of the Deep Water Horizon oil spill, certain issues became top priority. On the one hand, there was a need to stop the oil spill. However, while that goal was being worked on, mitigation procedures had to be developed for all the oil that was already spilling into the gulf. To make informed decisions about how to achieve these goals, an important variable that had to be measured was the flow rate of oil spewing out of the Macondo oil well. The flow rate was important for a number of reasons. First, the flow rate was considered an important factor in determining the success of the various options for shutting off the well. As a matter of fact, it is believed that the initial failure of the Top Kill procedure was due to wrong assumptions about the quantity of oil flowing out whereas the similar eventual static kill was more successful since no oil was flowing out. As a matter of fact, BP was aware that at flow rates of over 13,000-15,000 bpd, the Top Kill approach of pumping mud down the well would not work because mud would not be pumped down at a sufficiently high rate (1).

Determination of Oil Collection Capacity

The second use for flow rate calculations has to do with a particular mitigation effort – surface collection of oil. One temporary approach to addressing the oil spill was to place a cap known as a cofferdam above the well and collect all the oil spewing out, transferring it to surface vessels using risers. The flow rate was important in determining the capacity of these caps and the surface vessels doing the collection. Additionally, cofferdam use failed because frozen hydrocarbons, known as hydrates, clogged the cofferdam earlier than expected due to the low flow rate estimates. While later use of a similar device, *Top Hat* was moderately successful in collecting some oil, *Top Hat* and the production ship burning the collected oil were insufficient to collect all the oil spilling out due to underestimating of required collection capacity (1).

Dispersant Use

The third use of the flow rate calculations also had to do with another mitigation effort – use of dispersants. Dispersants are chemicals that break up the oil slick, coagulate it into tiny *micelles* that allow it mix with the water and sink to the bottom of the sea. However, the amount of dispersants applied has to be matched to the amount of oil spilled, which in turn is determined by the flow rate and the number of days the oil has been spilling for. The accuracy of dispersant application is important because too much dispersant will constitute unnecessary harm to the environment and cost to the cleanup and too little dispersant will result in oil slicks hitting the beaches or rising to the surface of the sea and threatening the health and safety of the responders. In the early days of the spill, insufficient dispersant use was informed by the government's low estimate of 5,000 bpd (1).

Oil Budget

Finally, the flow rate calculation was important for determining the oil budget which is an account of how much oil has been spilled and where it has gone: surface collection, dispersed, washed off at the beach, evaporated, burned off, skimmed at the surface etc. The oil budget is important for public accountability and for directing the cleanup effort even months after the well was closed. The flow rate calculation combined with the amount of time the oil spilled for provides an estimate of how much oil was spilled altogether which feeds into other models for dispersion and transport as well as records of cleanup efforts in order to estimate where the oil went (1).

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